

A Deep Learning-Based Real-Time Video Object Contextualizing and Archiving System

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Abstract— In recent years, we can see the presence of CCTV cameras everywhere in developed cities and urban areas. CCTV cameras are widely equipped in public places, buildings, and entertainment areas. Along with that popularity is the issue of effective management and exploration of CCTV cameras to ensure security and safety for people. With a huge data recorded from cameras, we need systems that support monitoring and analysis of camera data as well as instant video data retrieval. In this paper, we introduce a system to contextualize the video content recorded from CCTV cameras in real-time and store data efficiently. The big data generated from the system will make it easier to monitor and operate the camera system to access and search for objects and content in the surveillance cameras.

Keywords— Video object contextualizing, CCTV Cameras, Deep learning-based systems, Video archiving systems.

I. INTRODUCTION

Accompanying the development of society are issues related to ensuring security, social order, and monitoring people's activities in public places. Using effective monitoring mechanisms will help prevent as well as reduce criminal acts and violations of social order [1][2]. Using CCTV Cameras is an inevitable solution, popular in urban areas and big cities. Local governments are widely exploring and using CCTV cameras to ensure social order and security. Accompanying the use and operation of these CCTV camera systems is a matter of effective exploitation [3][4][5][6]. If the average data an HD camera (1280 x 720 / 720p) records in an hour is approximately 900Mb, the data generated from 10 cameras daily amounts to approximately 216Gb. To monitor a complex area, we need hundreds of cameras, and to manage a neighbourhood, this number has reached thousands of cameras. Hence, CCTV managers need effective control systems to access video data immediately and search for content through thousands of cameras. Some solutions have been introduced to deal with the management of large numbers of CCTV cameras and big video data analysis such as [7][8][9][10] and [11].

In parallel with the management and operation of CCTV camera systems is the issue of protecting people's privacy. Personal data of faces, time, and location appearing in public places must be protected in order to prevent crime situation [12][13][14][15]. With the emerging development of deep learning techniques, different approaches have been introduced and applied to protect the privacy of humans in CCTV cameras [16][17][18][19]. The main idea of these approaches is to detect and recognize the sensitive and personal information in the frame from the video and then blur these areas.

Currently, at most CCTV monitoring centers today, the monitoring activities are done manually with security staff. When an event occurs (e.g., fighting, traffic accident, crime), security personnel must search through numerous stored videos, playback each video, and extract the desired information. These activities are often time-consuming and sometimes miss information. To accommodate these activities, researchers have introduced some solutions to help retrieve information in video content, such as [20][21][22].

In this paper, we introduce an architecture and system to contextualize content from CCTV cameras. More precisely, In this approach, we have used YOLO [23], the common object detection algorithm, to detect objects from CCTV cameras in real-time and extracted the object's information to store in a JSON file following a specific proposed schema. Furthermore, our solution allows us to realize unlimited management of cameras (it depends on the hardware configuration of the management server) and optimize the extraction of information from cameras. The solution will support building future video content retrieval systems and optimizing video storage.

In the remaining of this paper, we organize the content as follows. In the next section, Related works, we discuss studies on big data video management systems and video contextualization approaches for retrieving content from CCTV videos. In section III, we describe the architecture of the deep learning-based real-time video object contextualizing and

archiving system and explain the functions of modules in the architecture. Section IV presents the experimental results of the proposed system for managing CCTV cameras in a kindergarten in Vietnam. Finally, section V concludes the paper and discusses future studies.

II. RELATED WORKS

In this section, we examine some recent research related to the big data CCTV video management mentioned in this paper to manage a huge number of centralized CCTV cameras as well as solutions to retrieve and store video content.

In [24], Xu et al. introduced a novel architecture for managing video surveillance system for public security with huge and heterogeneous video data generated from the system. In the study, they proposed a framework to present how to manage, organize, and store massive data of video generated from surveillance systems. The framework contains three modules: video intelligent analysis, policing repository database and the distributed file management. Although a system based on this architecture has not been built, the architecture has shown the feasibility of managing a huge number of CCTV cameras.

In [25], Tian et al. presented a block-level background modeling algorithm to support long-term reference structure for coding CCTV videos and proposed a rate-distortion optimization for the surveillance source algorithm to improve the coding performance. The main idea of their approach is that, in CCTV cameras, the background in video frames does not change, so they encoded the background only once, this activity reduces the redundancy of saving background repeatedly and hence saves the coding bits. Using this solution, they could reduce the size of the video to store from 4% to 26% depending on different resolution types of videos.

In [26], Kaseb et al. introduced a cloud management method for managing and analyzing videos from big data camera networks. The goal of the system is to reduce the overall cost to analyze a large amounts of visual data by using cloud services. The proposed system is created following two different stages: Offline stage and online stage. The offline stage is performed once and aims to determine the most cost-effective cloud instance. Meanwhile, the online stage is done in two steps, i.e., added cost is zero and allocate the appropriate number of cloud instances following the most cost-effective calculation equation.

In [27], Zhuo et al. conducted research on personalized image retrieval techniques from video stream data. In this study, they proposed a model named Multi-source big data fusion annotation to obtain similar personalized images. The model analyzed relevant multi-source knowledge of the personalized images and then annotated similar images. The main idea of retrieving personal images is based on calculating the total similarity of the personalized images and then assigning it to

each person. The retrieval function will compare the similarity values between different persons to display results.

In [28], Spolaor et al. conducted a systematic review of content-based video retrieval approaches for getting general pictures of retrieving content from videos. The study summarized the related research to answer the research question of what techniques and machine learning approaches have been used for content-based video indexing and retrieval. As shown in this study, video indexing and retrieval contain the following approaches:

- Segmentations: Entropy-based, color-based, machine learning based, cut-based.
- Feature extraction: Texture, motion-based, visual, color-based.
- Dimensionality reduction: Document frequency, Principal components analysis, K-means based.
- Machine learning: K-means based, nearest neighbours based, and support vector machines based.

In [29], Sauodi et al. introduced a content-based video retrieval system providing matching videos based on query videos from a large multimedia dataset. In the system, they have used vector motion-based signatures to demonstrate the visual content and deep learning algorithms to pull related frames from videos. In the beginning, the video sequence is divided into groups of pictures. Only the intra-compressed and forward-predicted frames are selected in these groups as candidate key frames. After that, the keyframe will be selected after extracting with three main steps (i.e., color feature extraction, distance measure, and frames clustering). After a signature distinguishes the videos, they will be compared by using a similarity measurement model.

The related studies indicated that creating a big data camera CCTV management system has attracted the interest of many research groups and still poses many challenges. Subsequently, how to build an efficient video retrieval system is a concern that researchers have recently devoted much effort to, especially in applying deep learning algorithms in these systems. In this study, not only proposed architecture for real-time video object contextualizing, but we also apply the architecture to create a system to extract detected object information to JSON files following a specific schema and implement the system to a real CCTV camera system in a kindergarten in Vietnam to evaluate the proposed approach. The results of this study will provide an efficient system for managing big data CCTV cameras and video retrieval systems. In the next section, we describe in detail the proposed architecture, its components, and functions.

III. ARCHITECTURE AND SCHEMA

In this section, we present the proposed architecture for deep learning-based real-time video object contextualizing and schema of JSON files for storing the information of detected objects in videos.

1. Architecture

The proposed architecture of our approach is described in Figure 1 in detail. The main idea of our method is that, first of all, the frames collected from CCTV cameras must be put in a frame queue for frame processing. After that, the system selects the frame following the priority of cameras to detect objects and extract information. The other frames in the queue will be combined and stored in the video storage. Using parallel processing with the YOLO object detect algorithm, we extract the information of the detected objects (bounding box, properties) and store them in a JSON file obeying a specific schema. In the architecture, we use FFmpeg and Vidgear open-source libraries for real-time processing video. The architecture contains the following components:

- CCTV: This component contains information on CCTV cameras, how to connect to a specific camera (address, login information, physical information, etc.)
- Real-time frame processing: This component manages the frames received from the CCTV cameras, then proceeds to queue a list of frames to be processed by priority. High-priority Frames will be put into the Frame Processing Module for pre-processing and then transferred to the Video object contextual machine. Frames with lower priority will be aggregated and stored in Video storage.
- Video object contextual machine: this component acts as the frame content detection. By using object detection algorithms (in this research, we use YOLO v5), the list of detected objects from the frame and its information will be saved in the form of a dictionary structure, and then pushed into a JSON file following the JSV structure (see the next section)
- Video storage and JSV storage: These two parts manage videos and JSV files that are aggregated and extracted from CCTV cameras to use in search functions in Video content retrieval systems.

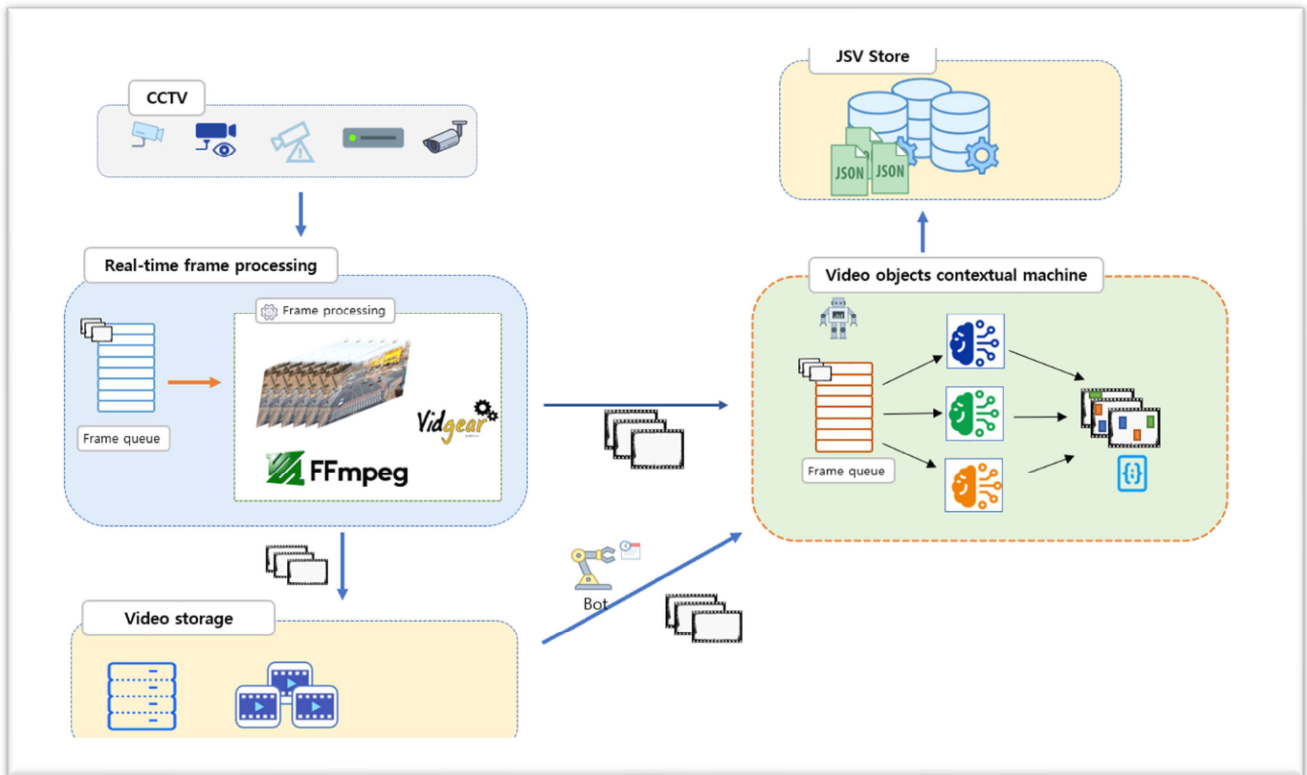


Figure 1. The proposed architecture

2. Video object contextual schema

In Figure 2, we illustrate the schema of the video object contextual mechanism. To be able to access and retrieve content in the video efficiently, we use a JSON file to store the information and call the file as JSV (Json video file format). The JSV file categorizes content in a dictionary-type containing

information about the video's metadata, the frames, the objects in the frame, and their properties. This information has many different characteristics, which are managed through Attributes. Many frames are organized by combining into Clips or Fragments regarding different CCTV cameras. This solution allows the video retrieval system to search for content in the

video later easily. As we can see in the Figure, the schema includes the following objects:

- Metadata
- Frame:
 - Clip
 - Fragment
 - Property:

- ID
- Detected object dictionary
- Detail: Detected object space

All objects are represented by Attributes with different value types such as, Enumerate, String, Date, Int, Float, List, Coordinate.

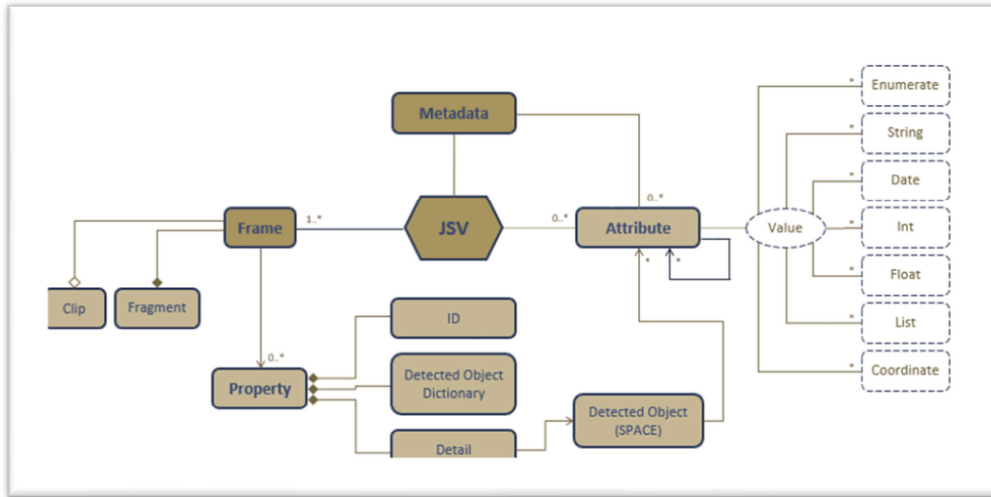


Figure 2. The Schema of JSON file for storing detected objects in CCTV videos

IV. EXPERIMENTAL RESULTS

To evaluate the proposed method, we built a system regarding the architecture and implemented the system to manage CCTV cameras in a kindergarten school group in Vietnam. The kindergarten contains 166 CCTV camera in six

campuses, each with 20 to 30 cameras. The collected videos and JSV files generated from the system are presented in Figure 3. As we can see in the figure, all the videos collected from the CCTV cameras are categorized into folders and files followings the structure. The video retrieval system can read both video content and JSV file together to retrieve information.

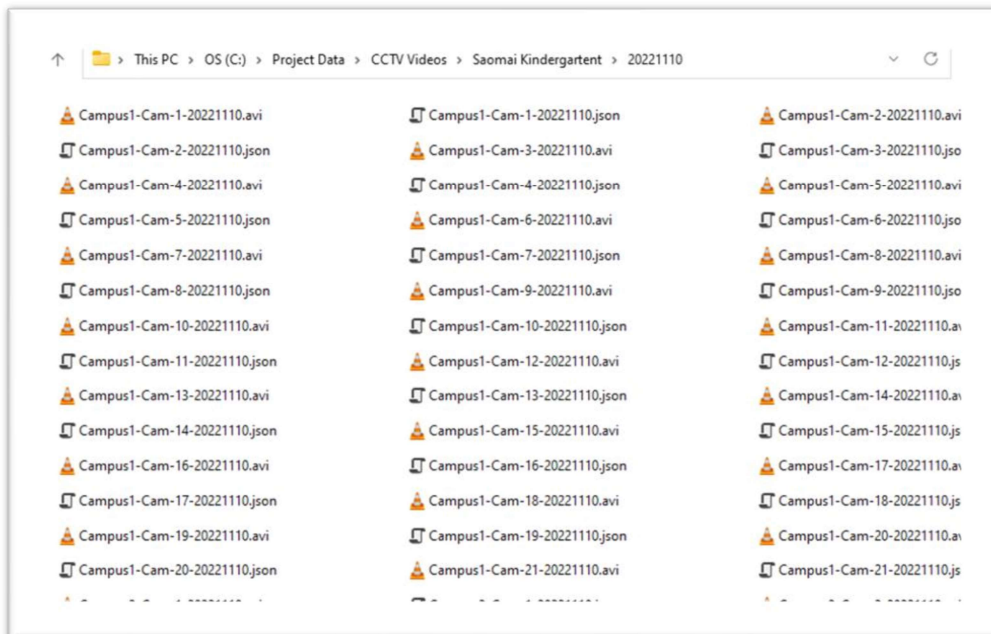


Figure 3. Collected videos and JSV files from the system

V. CONCLUSIONS

This paper introduced an architecture and system for real-time video object contextualizing and archiving system. In particular, we:

- summarize the recent studies on managing big data video management systems and video retrieval methodologies.
- proposed an architecture-based YOLO algorithm to detect objects from CCTV cameras and then extract all information to JSON file to store for retrieving data in the future.
- proposed a JSV format containing a schema for managing the content of objects detected from videos. The schema will support the video retrieval system in searching and exploring the content of CCTV video files.
- applied the proposed architecture to manage and store videos from a real CCTV system with 166 cameras.

Besides the obtained results, our proposal still has some limitations and needs to be overcome in future studies:

- The system has not yet applied a solution to compress video before archiving. As mentioned at the beginning of the paper, the data generated by each camera daily is very large, so we need to perform video compression before storing to reduce the space of Video storage.
- Video retrieval function is not integrated yet into the system.
- Information stored from the object extracted from the video only includes frame, object type, and location (bounding box). More attributes of the object in the video need to be detected and stored in the JSV file to support future searches. e.g., color, gender, size, distance.
- The generated JSV files are not indexed. File indexing will make it easy to find data when the number of files generated is very large (thousands of files per day).

In the upcoming studies, we will try to address these limitations as well as develop and put the system into a commercial version.

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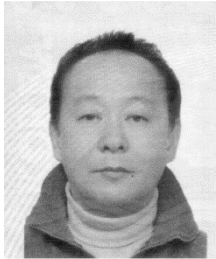
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